Soft and hard tissue changes after immediate implant placement with or without a sub-epithelial connective tissue graft: a randomized controlled clinical trial

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Abstract:

Objectives: investigation of the influence of connective tissue graft (CTG) in combination with immediate implant placement (IIP) on hard and soft tissues (ST) healing.

Materials and method: randomized controlled clinical trial investigating the efficacy of CTG when the implants are immediately placed in anterior maxilla and premolar area of 26 patients. Superimposed DICOM files together with the superimposition of DICOM and stereolithography files allows the evaluation of hard and ST dimensions at baseline and 6 months.

Results: No statistically significant differences between the groups (with or without CTG) are observed for vertical and horizontal resorptions of the buccal bone wall and for the keratinized tissue width, while significant differences were found in reduction of the alveolar ridge (-2.08±0.65 mm and -1.16±0.51mm), in changes of ST contours (from -1.94 to -1.08 mm and from -0.32 to -0.04 mm), ST thickness (from -0.16 to 0.88 and from 1.33 to 2.42 mm) and volume (0.16±0.49 and 6.76±8.94 mm^3) between control and test groups, respectively.

Conclusions: the adjunct of a CTG at IIP time reduces the horizontal resorption of the alveolar ridge that would otherwise occur, contributes to maintain the ST contour and increases ST thickness at implants sites.

Sintesi:

Obiettivi: studiare l'influenza di un innesto di tessuto connettivo in concomitanza al posizionamento implantare immediato sulla guarigione dei tessuti duri e molli.

Materiali e metodi: studio clinico randomizzato controllato che studia l'efficacia del CTG quando gli impianti sono immediatamente collocati nella mascella anteriore e nella zona premolare di 26 pazienti. I file DICOM sovrapposti insieme alla sovrapposizione di file DICOM e stereolitografici consentono la valutazione delle dimensioni dei tessuti duri e molli al baseline ed a 6 mesi.

Risultati: Non si osservano differenze statisticamente significative tra i gruppi (con o senza CTG) per il riassorbimento verticale e orizzontale della parete ossea vestibolare e per l'ampiezza del tessuto cheratinizzato, mentre sono risultate statisticamente significative la riduzione della cresta alveolare (-2,08±0,65 mm e -1,16±0,51mm), la contrazione orizzontale del contorno tissutale (da - 1,94 a 1,08 mm e da 0,32 a 0,04 mm), lo spessore (from -0.16 to 0.88 and from 1.33 to 2.42 mm) e l'aumento di volume dei tessuti molli (0,16±0,49 mm^3 e 6,76±8,94 mm^3), rispettivamente tra i gruppi controllo e test.

Conclusioni: il posizionamento di un innesto connettivale contemporaneamente all'inserimento di un impianto immediato riduce il riassorbimento orizzontale della cresta alveolare che altrimenti si verificherebbe, contribuisce a mantenere il contorno e aumenta lo spessore dei tessuti molli.

1. Introduction

Immediate implants have shown to be a predictable treatment for the replacement of non-restorable teeth. (Lang et al., 2012; Vignoletti & Sanz, 2014) However, compromised esthetic has been anticipated especially when utilized in the upper anterior maxilla. (Sanz et al., 2010; Cecchinato et al., 2015; Cosyn et al., 2013)

Most of the attention in the literature has been paid to hard tissue healing and several strategies have been adopted to limit the horizontal and vertical dimensional changes that occur after extraction and immediate implant placement (IIP), such as flapless surgeries, bone grafting, guided bone regeneration, immediate loading. Overall, it may be agreed that between 10-30% of buccal bone resorption should be expected. (Thoma et al., 2014) Nevertheless, although it has been suggested that this bone dimensional changes are compensated by soft tissue during early healing (Chappuis et al., 2017), the reduction of soft tissue contour on long term healings may greatly affect the aesthetic outcome of the prosthetic reconstruction.

Therefore, it becomes apparent that soft tissue management with the use of connective tissue grafts (CTG) around implants is of outmost importance to mimic natural ideal conditions and for this reason it has become a topic of growing interest for clinicians. (Cairo et al., 2019)

Therefore, the purpose of the present RCT was to investigate the influence of a CTG in combination with the IIP on hard and soft tissues healing, without a bone replacement graft in the gap between the implant and the socket walls.

2. Materials and methods

2.1 Study design

The study was designed as a randomized controlled clinical trial with a parallel design, single blinded, performed at the Dental Department of San Raffaele Hospital (Milan, Italy). The study protocol was approved by the Ethical Committee of San Raffaele Hospital, registered on clinicaltrial.gov and performed in accordance with the Helsinki Declaration of Human Studies. All subjects gave written informed consent.

2.2 Patients' sample

Adults (≥18 years of age) were screened on the bases of having single hopeless tooth candidate for extraction in the maxillary or mandibular area (from second premolar to second premolar) in need of a single implant supported fixed prosthetic rehabilitation.

Patients were selected on the bases of fulfillment of the following inclusion criteria:

- presence of intact walls of the socket after tooth extraction, with maximum 3 mm of buccal dehiscence;
- distance between interdental bone crest and buccal bone crest ≤3mm after tooth extraction.

Patients were excluded if they had any of these conditions: general contraindications for dental and/or surgical treatments, inflammatory and autoimmune disease of oral cavity, uncontrolled diabetes, concurrent or previous immunosuppressant, bisphosphonate, or high-dose corticosteroid therapy, concurrent or previous radiotherapy of head area, smokers (>10 cigarettes a day), pregnant or lactating women.

2.3 Randomization and allocation concealment

The study was powered to detect a minimum clinically significant difference in radiographic changes of ridge height on CBCT of 1 mm using α=0.05, a power=80% and a hypothesized within-group sigma of 0.9 mm, obtained from previous studies. (Jung et al., 2013) As a minimum, 13 patients per treatment arm were selected for power analysis calculation. 15 patients were the final number considering possible dropouts.

Patients were assigned to one of the two treatment groups with the use of computer-generated randomization table (test group: immediate implant + connective tissue graft; control group: immediate implant).

The sealed opaque envelope containing the allocation concealment was opened during surgery after implant placement.

2.4 Treatments

Surgeries were performed by one surgeon (D.G.) at the Dental Clinic of the San Raffaele Hospital.

After local anesthesia, a buccal split-full-split thickness envelope flap, as described for the treatment of multiple gingival recessions by Zucchelli and de Sanctis (2000), was elevated and the tooth was extracted a-traumatically.

The mesial and distal anatomic papillae were maintained in place and de-epithelialized to create connective tissue vascular beds and to support the flap after suturing.

After preparing the osteotomy a Winsix KE (Biosafin) implant was immediately inserted with 1 mm of the transmucosal portion of the implant positioned under the buccal bone crest.

In the test group a CTG, resulting from the extraoral de-epithelialization of a free gingival graft harvested from the palate, was positioned over the buccal bone crest and anchored to the anatomic papillae with single interrupted sutures, carefully positioned in contact with the implant surface, in such a way to covering completely the buccal gap, and in the apical direction 2 mm above the buccal crest.

In both groups of implants healing abutments were secured. The buccal flap was coronally advanced by means of deep and superficial split-thickness incisions and the flap was tightly adapted to the healing abutment. Modified sling sutures were performed to accomplish an accurate adaptation of the buccal flap on the implant surface and to stabilize every single surgical papilla over the interdental connective tissue bed of the anatomical papilla.

A provisional Maryland restoration prosthetic crown was subsequently delivered.

Adequate hygiene and dietary instructions were given to the patient for the postsurgical period. (Figure 1)

2.5 Clinical measurements

Clinical measurements were performed at the time of implant placement taken by a blind examiner (G.L.D.D.) to the nearest millimeter using a periodontal probe.

The width of keratinized tissue (KT Width) was measured at the buccal aspect, prior to tooth extraction. After the extraction and flap elevation, the following parameters were assessed:

- BC Thick, thickness of the buccal bone wall, that was measured 2 mm apical of the most coronal buccal bone crest using a caliper;

After implant placement, a gap occurred between the implant surface and the buccal bone wall of the extraction socket. The following measurements were taken:

- S-IC - the horizontal distance between the implant surface and the inner surface of buccal bone crest;

- S-OC - the horizontal distance between the implant surface and the outer surface of the buccal bone crest. (Figure 2)

2.6 Hard tissue measurements

A cone-beam computed tomography (CBCT) scan of the relevant site was performed prior to tooth extraction (BL) and 6 months after implant placement (6M), to evaluate hard tissue dimensional changes. (Figures 3-4)

DICOM image superimposition was used to assess the horizontal and vertical linear buccal bone resorption which occurred after 6 months of healing following the two different treatment modalities. All radiographic superimpositions and measurements were carried out by one calibrated and blinded examiner (V.C), as described by Sanz-Martin et al. (2019).

Baseline DICOM files were first converted into a stereo lithography (STL) file and then superimposed to 6M DICOM file by selecting common reference points from the adjacent tooth surfaces.

The following landmarks were identified in the cross-sectional image:

- point A, the bucco-coronal point of the buccal plane of the baseline socket;
- point B, the bucco-coronal point of the buccal plane at 6 months after implant insertion.

Five parallel lines were drawn perpendicular to a line coinciding with the longitudinal axis of the implant and at 1, 2, 3, 4 and 5 mm below to the point A and the following parameters were recorded:

- HBBR, horizontal buccal bone resorption, that was the horizontal linear distance between the outer surface of buccal bone at BL and those at 6M (measurements were expressed in mm and %);
- ORW, osseus ridge width, that was the horizontal linear distance from outer surface of buccal bone to outer surface of palatal/lingual bone, measured at baseline and at 6 months;

- VBBR, vertical buccal bone resorption, that was calculated by measuring the vertical linear distance from point A to point B.

2.7 Soft tissue measurements

The relevant upper/lower jaw segment was optically scanned using a 3D scanner in order to create stereolithography (STL) files and assess soft tissue dimensional changes occurring between baseline examination (BL) and 6 months after implant placement (6M).

Soft tissue contour (Figures 5 and 6)

STL file superimposition and soft tissue dimensional changes measurements were executed by one calibrated and blinded examiner (V.C), using a methodology described by Sanz-Martin et al. (2019). BL and 6M STL files of each patient were matched using a volume comparative software program.

The superimposed files were used to evaluate both the horizontal linear and volumetric buccal soft tissue contour changes which occurred 6 months after implant placement in the two different treatment groups.

Soft tissue thickness (Figure 7)

Superimposition of DICOM file, representing hard tissue volume, to STL file representing soft tissue contour, was used to measure the buccal soft tissue thickness in the two different treatment groups. DICOM-STL analysis were performed by one calibrated and blinded examiner (V.C) adopting a methodology reported by Sanz-Martin I. et al. (2019). The buccal soft tissue thickness (STT) was then evaluated by measuring at these different heights, the linear distance between the buccal soft tissue outline to the buccal bone at BL and 6M and was expressed in mm.

2.9 Statistical analysis

Mean and standard deviation for continuous variables was used as indices of centrality and dispersion of the variable distribution. For testing the differences between the two groups, the non-parametric test as Wilcoxon rank-sum test, was used.

The test of equality for matched data was used to compare the difference between pairs of observation in the groups in time.

The Spearman rank correlation coefficient was used to test the strength and direction of association that may exist between two variables examined. When testing the null hypothesis of no association, the probability level of error at two tails was 0.05.

All of the statistical computations were made using StataCorp 2021 (Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC).

3. Results

3.1 Study population

Patient recruitment was conducted from November 2018 to December 2020. The cause for the tooth extraction was several, and included root fracture, caries, root resorption, or endodontic failure.

30 patients were enrolled; of these, 4 patients did not complete the follow-up evaluation. Finally, a total of 26 patients with 26 implants were included and attended the 6-month follow-up examination. The sample consisted of 14 women and 12 men with a mean age of 53.4±12.4 years (range: 34-74 years).

Twenty-two implants were placed in the maxilla and four in the mandible. Three implants were located at incisor sites and 23 at premolar sites. A CTG was applied in 15 implants (test group).

3.2 Clinical outcomes

At baseline, the thickness of the buccal bone measured at 2 mm from bone margin, ranged from a minimum of 0.2 mm to a maximum of 1.9 mm, but did not reveal any statistically significant differences between the two treatment groups (p=0.41).

After immediate implant placement, the mean horizontal buccal gap was 2.59±0.92 and 2.73±0.90 mm, while the vertical depth of the gap was 8.18±1.72 and 7.90±2.02 mm, in the control and test group respectively. The difference between the groups was not statistically significant. (Figure 2)

All implants healed adequately without any complications.

3.3 Hard tissue dimensional changes

Horizontal changes

The majority of the horizontal changes of the buccal bone (HBBR) occurred at 1mm below the most coronal aspect of the buccal wall with similar changes between the two treatment groups. (Figure 3 - Table K) They were in fact -1.59±0.63mm (44.62±19.86%) for the control group and -1.36±1.17mm (38.82±26.56%) for the test group, without statistically significant differences (p=0.13 and p=0.55, respectively).

When evaluating the osseous ridge resorption (ORR), that is the mean reduction of the alveolar crest in the bucco-lingual width (measured as difference between ORW at baseline and ORW at 6 months), the results indicated -2.08±0.65 mm (22±6%) and -1.16±0.51mm (14±6%) of horizontal dimensional changes at 1 mm in control and test groups, respectively. These differences were statistically significant (p=0.001 and p=0.018, respectively). (Figure 4 - Table X)

Vertical changes

The mean loss in height (VBBR) amounted to -0.66 ± 0.53mm in the test group and -0.66 ± 0.75mm in the control group, with no significant differences (p=0.75). (Figure 3 - Table K)

Factors influencing bone resorption

The correlation analysis identified a negative significant relationship between the osseous ridge width resorption (ORR) and the peri-implant soft-tissue phenotype, that includes soft tissue thickness at baseline and the CTG thickness (r= -0.46, p=0.017).

3.4 Soft tissues dimensional changes

Tissue contour

At 6-month follow-up examination, a horizontal reduction ranged between -0.32 and -0.04 mm in the test group, and between -1.94 and -1.08 mm in the control group. The pairwise analysis showed statistically significant differences between the two groups at all levels. (Figure 5 - Table Y)

At 6 months, the mean volume increase was 6.76±8.94 mm^3 and 0.16±0.49 mm^3 in the test and control groups, respectively, with statistically significant difference (p=0.002). (Figure 6 - Table W)

Soft tissue thickness

After 6 months, the test group experienced significantly more tissue thickness gain at 1, 2, 3, 4 and 5 mm from the gingival margin than the control group compared to baseline. This change ranged between 1.33 and 2.42 mm in the test group, and between -0.16 and 0.88 mm in the control group. (Figure 7 - Table Z)

Soft tissue width

At 6-months follow-up, the mean keratinized width was 3.64±1.29 mm and 4.53±1.36 mm in the control and test groups respectively, with no statistically significant difference (p=0.102). There was a gain in the amount of keratinized tissue, that was of 0.14±1.52 mm and of 0.6±1.71 mm in the control and test groups respectively (p=0.482).

4. Discussions

The present investigation is designed to evaluate the influence of a connective tissue graft in combination with the immediate implant placement on hard and soft tissues healing responses. Results demonstrate that the use of a connective tissue graft influenced horizontal dimensional changes of the alveolar ridge, contributed to maintain the soft tissue contour and increase soft tissue thickness at implant sites.

Hard tissue dimensional changes

According to the previous investigations, the present study confirms that this procedure fails to prevent the horizontal and vertical ridge alterations. (Araujo et al., 2005; Discepoli et al., 2015; Vignoletti, Discepoli, et al., 2012; Vignoletti, Matesanz, et al., 2012; Vignoletti & Sanz, 2014)

Data of the present study reveals a horizontal ridge width reduction of 2.08±0.65 mm (22±6%) for the control group and 1.16±0.51mm (14±6%) for the test group, with statistically significant differences.

The amount of osseous ridge resorption observed in the control sites is comparable to the data reported by previous studies, namely Botticelli et al. (56%), Sanz et al. (36%), Sanz et al. (16%). (Botticelli et al., 2004; Sanz et al., 2010; Sanz et al., 2017)

On the other hand, results from test group are similar to with the results obtained with the use of a bone substitute graft in the gap between the implant surface and the bone wall: Sanz et al. reported horizontal

mean changes of -1.26±1.75mm (-11%), whereas Clementini et al. a reduction of 1.29 ± 0.38 mm (14.9 ± 4.9%). (Sanz et al., 2017; Clementini et al., 2019) Therefore, it is conceivable that the connective tissue graft will exert a protective effect to the buccal bone loss, both augmenting the soft tissue thickness and providing a precise closure of the gap, because of the close adaption of the graft to implant surface.

The utilization of the proposed surgical technique, the modified coronal advanced flap with split-full-split approach, maintains the integrity of the periosteal vascularization into the flap, being elevated full thickness in the coronal portion, and it is ideal for flap closure that should be relatively passive and tension-free. Also, this technique presents other advantages due to the absence of vertical incisions, that will improve both flap vascularization and stability (Zucchelli et al., 2009), while the coronal position of the margin will reduce the risk of flap shrinkage. (Baldini et al., 2010) Also, interdental papillae were not elevated, but maintained in position, this could be another factor could explain the buccal bone protective effect.

When evaluating vertical bone loss, results of the present study show that at 6-months no reduction of the bone height can be demonstrated, both in test and control groups. These data suggested that regardless to the thickness of buccal bone, the height of the bone and thus the contact with the implant shoulder is not modified during the healing phases, that is a stable bone-to-implant relation can be achieved even in the presence of a thin buccal socket wall (<1 mm). These data are in agreement with Sanz et al., that reported 0.3 mm of vertical changes at the buccal crest both in the test and the control groups. (Sanz et al., 2017)

Soft tissue findings

Volumetric measurements using STL data demonstrated a pronounced augmentation in tissue contour for CTG group (6.76±8.94 mm^3) when compared to control sites (0.16±0.49 mm^3) at 6-months follow-up visit.

The observed loss of tissue volume that occurred in the control group may be due to the reduction in width of the osseus ridge, that was not completely compensated by the physiological increase in tissue thickness. (Chappuis et al., 2015)

The tissue contour in the test group was maintained at all level of the measurements, including in the most coronal zone at the level of transmucosal area.

When comparing the effect of a connective tissue graft on tissue contours after IIP it should be taking into account that no previous investigations have maintained an empty gap but all utilized bone grafting in the gap. Nevertheless, the results of current study were similar to a recent study by Jiang et al. (2020), that showed significantly less tissue collapse for the test groups in the area 2–5 mm apical to the gingival margin, but not at 1 mm (0.89±0.48mm for the test group (bone graft+CTG) and 1.07±0.45mm for the control group (bone graft), with p=0.183). This difference could be explained by a more precise surgical technique used in the current study. In fact, in the study of Jiang et al. the implant was positioned flapless and the CTG was inserted beneath the buccal flap by the tunneling technique, without sutures, and probably it was pushed by the pressure of the provisional crown. (Jiang et al., 2020)

Soft tissue thickness had a statistically significant increase for CTG sites when compared to control group at 6 months follow-up. Hence, it appears clear that the placement of a connective tissue graft maintained the tissue contour and compensated the bone resorption.

5. Conclusion

Despite the limitations, the present study demonstrates that the adjunct of a connective tissue graft at the time of immediate implant placement, without bone grafting, reduces the horizontal changes of the alveolar ridge that occur following immediate implant placement. Moreover, it compensates the reduction in tissue contour due to an increase in soft tissue thickness. Further trials with long-term follow-up and larger sample of patient are needed.

6. Figures and Tables

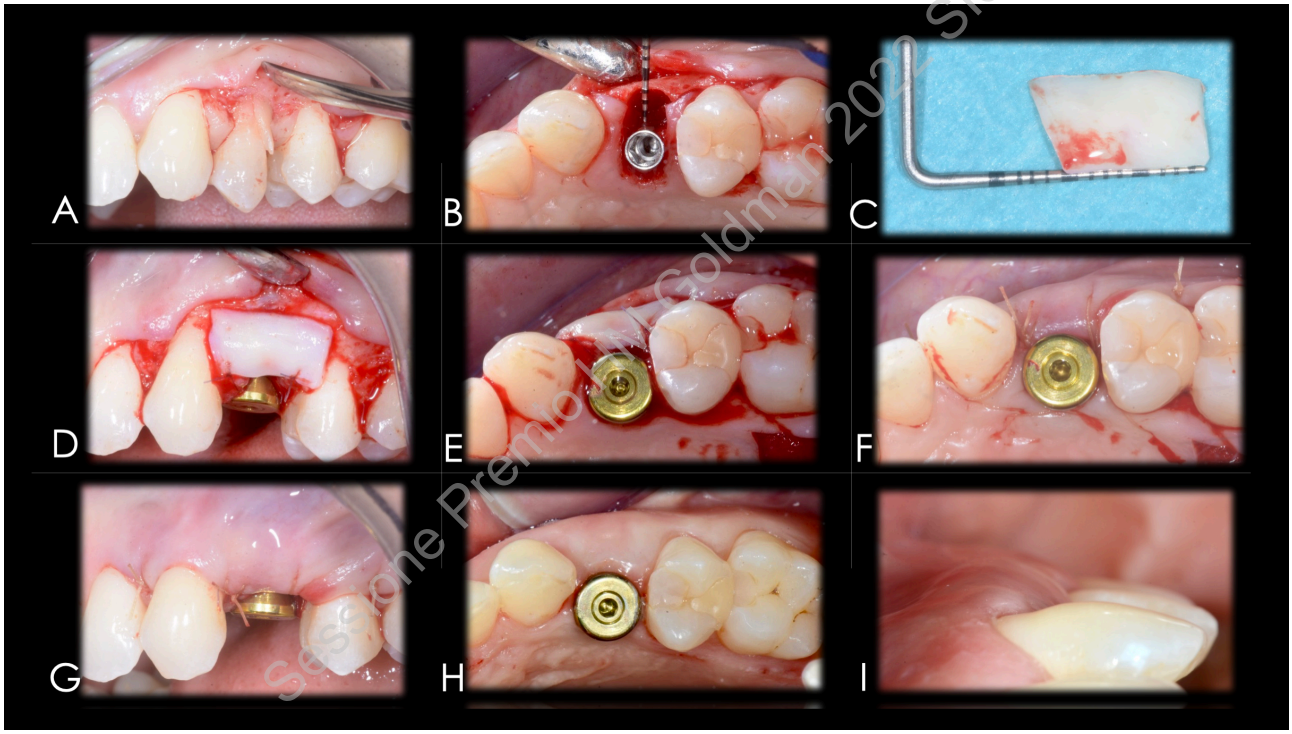


FIGURE 1 _ Treatments

A_ Flap incision and buccal view of the extraction tooth.
B_ Occlusal view at implant insertion.
C_ Connective Tissue Graft harvested from the palate.
D_ Buccal view of the positioning and suturing of the connective tissue graft.
E_ Occlusal view of the positioning and suturing of the connective tissue graft.
F_ Occlusal view of flap closure.
G_ Buccal view of flap closure.
H_ Occlusal view of the peri-implant tissues at 6 months.
I_ Side view of the peri-implant tissues at 6 months.

Table H

	CTG=0 (md±sd)	CTG=1 (md±sd)	*p* value *
BC Thick (mm)	1.04±0.58	0.84±0.39	0.41
S-IC (mm)	2.59±0.92	2.73±0.90	0.73
S-OC (mm)	3.66±0.90	3.54±1.03	0.65
IC-IC (mm)	8±1.2	8.47±1.19	0.39
OC-OC (mm)	10.4±1.29	10.32±1.36	0.92

* Wilcoxon rank-sum test (Mann-Whitney).

BC Thick: buccal bone thickness;
S-IC: internal horizontal buccal GAP size;
S-OC: horizontal buccal crest dimension (bucco-lingual dimension from implant to buccal bone);
IC_IC: bucco-lingual dimension of the socket;
OC-OC: bucco-lingual dimension of the crest (from outer crest to outer crest)

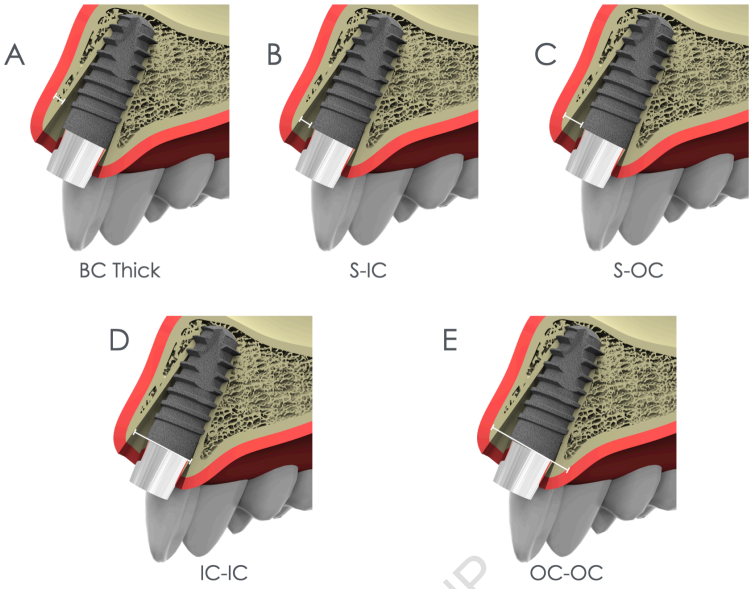


FIGURE 2 _ Clinical Measurements

Table H: Clinical outcome variables with mean and standard deviation

A to F: Landmarks used to describe the dimension of the ridge as well as the size of the gap between the implant and the socket walls
A_ BC Thick, thickness of the buccal bone wall measured 2 mm apical of the most coronal buccal bone crest
B_ S-IC, internal horizontal buccal gap dimension: the width of the gap between the implant surface and the inner surface of buccal bone crest
C_ S-OC, horizontal buccal crest dimension (bucco-lingual dimension): the distance between the implant surface and the outer surface of the buccal bone crest
D_ IC-IC, bucco-lingual dimension of the socket: the distance between the inner surfaces of the buccal and lingual bone crest
E_ OC-OC, bucco-lingual dimension of the crest: the distance between the outer surfaces of the buccal and lingual bone crest.

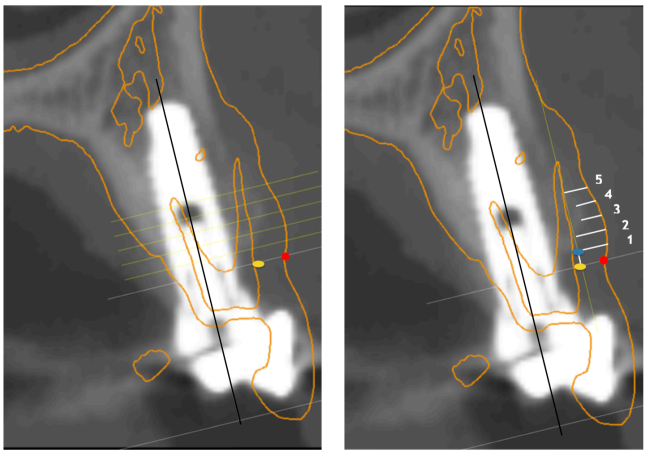


Table K

	CTG=0 (md±sd)	CTG=1 (md±sd)	*p* value *
HBBR 1 (mm)	-1.59±0.63	-1.36±1.17	0.13
HBBR 2 (mm)	-1.13±0.47	-0.89±0.70	0.19
HBBR 3 (mm)	-0.96±0.44	-0.73±0.53	0.18
HBBR 4 (mm)	-0.79±0.40	-0.69±0.39	0.55
HBBR 5 (mm)	-0.78±0.40	-0.66±0.45	0.27
%HBBR 2 (HBBR 2 / S-OC)	44.62±19.86	38.82±26.56	0.55
VBBR (mm)	0.66±0.75	0.66±0.53	0.75

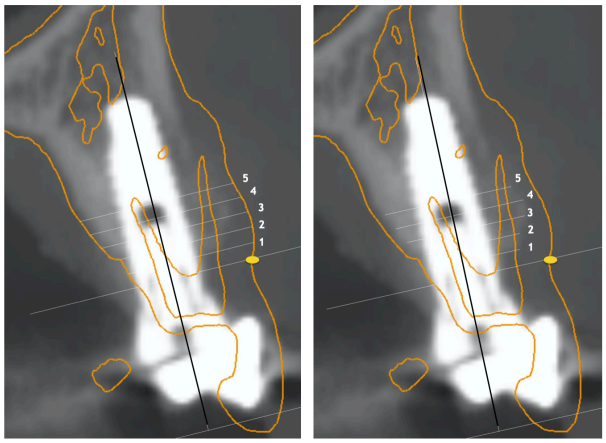
* Wilcoxon rank-sum test (Mann-Whitney).
HBBR: horizontal buccal bone resorption; VBBR: vertical buccal bone resorption;
S-OC: horizontal buccal crest dimension (bucco-lingual dimension from implant to buccal bone);

FIGURE 3 _ Hard Tissue Measurements - Buccal Bone Crest Dimension

DICOM images superimposition of crestal contours.
Baseline (orange) (DICOM file converted into a STL file) and 6M (DICOM file) images superimposed by selecting common reference points from the unchanged tooth surfaces.
Five parallel slight yellow lines perpendicular to a line coinciding with the longitudinal axis (black lines) of the implant represent the linear measurements made 1, 2, 3, 4, and 5 mm below the most coronal point of the BL buccal osseous ridge (red points).
The horizontal buccal bone resorptions (HBBR) were calculated by measuring at these different heights, the horizontal linear distance between the outer surface of buccal bone at BL and at 6M (white lines).
The vertical buccal bone resorptions (VBBR) were calculated by drawing a line parallel to the longitudinal axis of the implant and then by measuring the vertical linear distance between the most coronal point of the buccal osseous ridge at BL (yellow points) and at 6M (blue points).

Landmarks:
yellow points = point A in the main text: bucco-coronal point of the buccal plane of the baseline socket;
blue point = point B in the main text: the bucco-coronal point of the buccal plane at 6 months after implant insertion;
red points: the most coronal point of the BL buccal osseous ridge at baseline.

TABLE K: Hard tissue dimensional changes _ Horizontal and Vertical Buccal Bone Resorption (measurements were expressed in mm and %)



A B

Table X

	CTG=0		CTG=1		*p* value*	
	mm (md±sd)	%	mm (md±sd)	%	mm	%
ORR 1	- 2.08±0.65	22±6%	- 1.16±0.5	14±6%	0.003**	0.018**
ORR 2	- 1.66±0.95	17±9%	- 1.03±0.66	11±7%	0.084	0.095
ORR 3	- 1.45±0.89	15±8%	- 0.95±0.6	10±6%	0.244	0.239
ORR 4	- 1.13±0.69	12±7%	- 1.05±0.68	11±7%	0.721	0.678
ORR 5	- 1.06±0.58	11±6%	- 0.94±0.56	10±5%	0.443	0.467

* Wilcoxon rank-sum test (Mann-Whitney).
** statistically significance
ORR: osseus ridge resorption

FIGURE 4 _ Hard Tissue Measurements - Osseus Ridge Changes
Five parallel slight yellow lines perpendicular to a line coinciding with the longitudinal axis (black lines) of the implant represent the linear measurements made 1, 2, 3, 4, and 5 mm below the most bucco-coronal point (yellow points) of the buccal plane of the baseline socket.

Osseous ridge width: (ORW) osseous ridge width, that was the horizontal linear distance from outer surface of buccal bone to outer surface of palatal/lingual bone (OC-OC) measured at baseline (DICOM file converted into a orange STL file - Figure 4.A) and at 6 months (DICOM file - Figure 4.B) image.

Osseous Ridge Resorption: (ORR) the horizontal linear difference between the distance from ORW at baseline (DICOM file converted into a orange STL file - Figure 4.A) and at 6 months (DICOM file - Figure 4.B).

Landmarks:
yellow points = point A in the main text: bucco-coronal point of the buccal plane of the baseline socket.

TABLE X: Hard tissue dimensional changes _ Horizontal Changes -
Osseus Ridge Resorption (ORR) (measurements were expressed in mm and %)

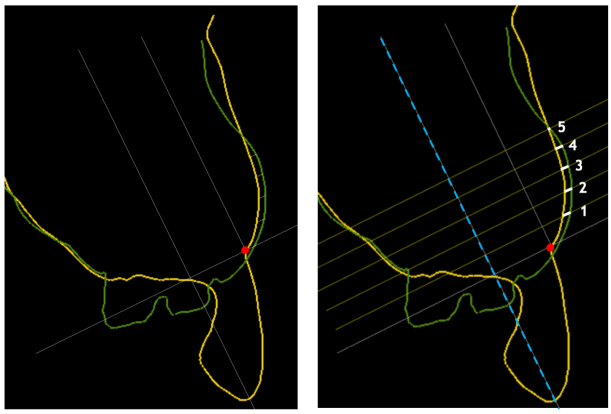


Table Y

	CTG=0	CTG=1	*p* value*
Δ STC 1	-1.94±0.99	-0.32±0.97	0.002**
Δ STC 2	-1.85±0.92	-0.04±0.74	<0.0001**
Δ STC 3	-1.57±0.75	0.11±0.66	<0.0001**
Δ STC 4	-1.30±0.75	0.18±0.70	0.0002**
Δ STC 5	-1.08±0.80	0.13±0.81	0.003**

* Wilcoxon rank-sum test (Mann-Whitney).
** statistically significance
Δ STC: soft tissue contour changes

FIGURE 5 _ Horizontal linear soft tissues measurements

STL image superimposition of soft tissue contours. Baseline (yellow) and 6 months (green).
Five parallel slight yellow lines perpendicular to a line coinciding with the longitudinal axis (blue dotted line) of the tooth crown represent the linear measurements made 1, 2, 3, 4, and 5 mm below the gingival margin (red points).
The buccal soft tissue contour changes were calculated by measuring at these different heights, the horizontal linear distance (white lines) between the buccal soft tissue contour at BL (yellow) to 6M (green).

- red points: gingival margin (at baseline).

TABLE Y: Horizontal soft tissues contour changes _ Linear measurements (measurements were expressed in mm)

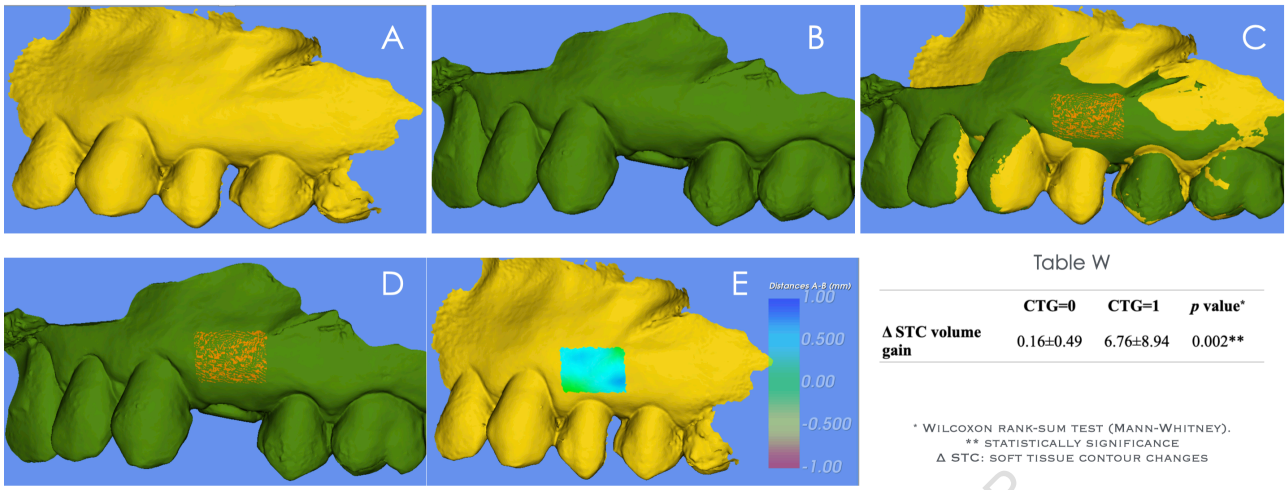


Table W

	CTG=0	CTG=1	*p* value*
Δ STC volume gain	0.16±0.49	6.76±8.94	0.002**

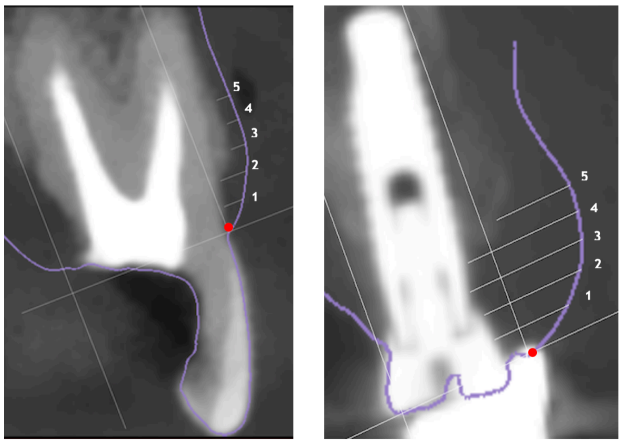
* Wilcoxon rank-sum test (Mann-Whitney).
** statistically significance
Δ STC: soft tissue contour changes

FIGURE 6 _ Horizontal linear soft tissues measurements

A to E: Volumetric analysis by superimposition of STL files.
A_ baseline (yellow).
B_ 6 months (green).
C_ superimposed files at baseline and 6 months.
D_ superimposition showing the area of volumetric variations (orange).
E_ superimposition showing gradients of volumetric variations.

Volumetric measurements (Δ STC volume gain) were performed by selecting an area of interest delimited apico-coronally by the gingival margin of the tooth and the mucogingival line and mesio-distally by a vertical line passing through the center of interdental papillae.

TABLE W: Horizontal soft tissues contour changes _ Volumetric measurements
Soft Tissue Contour Changes: Δ STC volume gain (measurements were expressed in mm3)



A B

Table Z

	CTG=0	CTG=1	p*
Δ STT 1	-0.16±0.72	1.47±1.08	0.0001**
Δ STT 2	0.12±0.83	2.04±1.18	0.0002**
Δ STT 3	0.81±1.14	2.42±1.63	0.007**
Δ STT 4	0.88±1.05	2.07±1.22	0.02**
Δ STT 5	0.11±0.90	1.33±1.17	0.01**

* Wilcoxon rank-sum test (Mann-Whitney).
** statistically significance
Δ STT: soft tissue thickness changes

FIGURE 7 _ Soft tissues measurements

A_ Baseline DICOM representing hard tissue dimensions and STL files (violet) representing soft tissue contours superimposed, allowing the evaluation of baseline soft tissue thickness. Slight white lines represent the soft tissue thickness 1, 2, 3, 4, and 5 mm below the gingival margin (red points).
B_ 6-month DICOM representing hard tissue dimensions and STL files (violet) representing soft tissue contours superimposed, allowing the evaluation of 6 months soft tissue thickness. Slight white lines represent the soft tissue thickness 1, 2, 3, 4, and 5 mm below the gingival margin (red point).
The Δ buccal soft tissue thickness (Δ STT) was then evaluated by measuring at these different heights, the linear distance between the buccal soft tissue outline to the buccal bone at BL and 6M.

TABLE Z: Horizontal soft tissues changes _ Buccal soft tissue thickness changes (measurements were expressed in mm)

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